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AIR POLLUTION EMISSIONS

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Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

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U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Public Health Service

Robert A. Taft Sanitary Engineering Center
Cincinnati 26, Ohio

*Community Air Pollution Program

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For an air pollution problem to exist there must be present a source of airborne pollutants and an adversely affected population or environment. Consequently, detailed knowledge of the types and quantities of emissions to the atmosphere is fundamental to an understanding of the nature and magnitude of urban air pollution. The particular degree of definition required in an inventory of emissions is related to the general objectives and scope of the air pollution study.

An emission inventory of an urban community provides such essential information as: (a) Relative contribution of the respective sources of pollution to the overall loading of the atmosphere; and (b) The relative amounts of each of the different types of pollutants involved. This kind of information is necessary to the intelligent interpretation of results from atmospheric sampling, and for the establishment of a base line against which to relate future trends in air pollution emissions and atmospheric concentrations. Emission data may be utilized to estimate potential atmospheric concentrations of selected pollutants under specified meteorological conditions.

In conducting an emission inventory, sources may conveniently be divided into two major classes, specific sources, largely industrial, which are studied on an individual basis and multiple sources, those too numerous to be treated individually. This latter class includes automobiles, trucks, residences, apartments, incinerators and many other sources which collectively contribute significantly to urban air pollution.

For purposes of illustration, the following discussion will be limited to a description of the air pollution emission inventory presently under development as part of the Special Air Pollution Study of Louisville-Jefferson County, Kentucky. This is a two-year study, initiated in January 1956, under the technical direction of the Community Air Pollution Program of the Public Health Service, Taft Sanitary Engineering Center, Cincinnati, Ohio, in cooperation with other Federal agencies as well as County and City agencies with substantial financial assistance from local industries.

MULTIPLE SOURCE INVENTORY

The purpose of the Multiple Source Inventory is to determine the collective contribution to atmospheric pollution from all major emitters which, for practical reasons, are not assayed directly on an individual basis.

Transportation

In a typical American community one of the most important multiple sources of air pollution is the motor vehicle. This opinion is based on considerations not only of total quantity of emissions involved but also of the nature of the pollutants which, according to the latest theories,

are capable of entering into photochemical reactions which produce objectionable effects.

Auto exhaust contains significant quantities of nitrogen oxides, sulphur oxides, aldehydes, ammonia and aerosols. Additives to gasoline and oil give rise to other pollutants such as compounds of lead. In addition, large quantities of gasoline vapors are emitted through the engine exhaust gases as well as by evaporation from gasoline tanks and carburetors and in gasoline handling operations in general. Exhaust products from diesel engines are similar in type to those from automobiles but vary significantly in the relative amounts of the various components.

From extensive research and experimentation by several investigators, notably Los Angeles County Air Pollution Control District, Stanford Research Institute, and the automobile industry, has emerged extensive data on the composition of exhaust gases from internal combustion and diesel engines in terms of the relative amounts of each of the major components. This information is reported in terms of weight of exhaust component per unit volume of gasoline or diesel oil consumed. Thus it is possible to calculate the emissions from automobiles, trucks, and busses in a given area from information on the volume of the respective motor fuels consumed in that area. Emissions from locomotives powered by gasoline and diesel oil may be estimated as in the case of motor vehicles. Using a procedure developed by the American Petroleum Institute and the Los Angeles County Air Pollution Control District it is possible to calculate the hydrocarbon losses from gasoline storage tanks.

Steam-operated locomotives and vessels constitute another, although gradually diminishing, source of pollution from transportation. The emission rates of flyash and sulphur dioxide can be calculated from available figures of tonnage and composition of coal and fuel oil used, with due consideration to combustion equipment and practices.

Combustion of Fuels for Heat and Power

The burning of fuels for the production of power and hot water, heating of homes, apartments, public and private buildings, represents an important source of air pollution. The emissions from this source may be estimated by calculations based on the rates of consumption of fuel oil, manufactured and natural gas, coal and wood. Fuel consumption figures may be obtained from the American Petroleum Institute, Bureau of Mines, public utilities, and local fuel distributors.

The products of combustion of fuel oil, gas and coal include oxides of sulphur and nitrogen, hydrogen sulfide, hydrogen cyanide, formaldehyde, organics, fluorides, acids and aerosols in varying amounts depending on the particular fuel. Applying data on the relative amounts of these emissions to the individual rates of fuel consumption, it is possible to calculate the daily emission rates of each component in such terms as tons produced per ton of each type of fuel burned.

Incineration of Solid Wastes

The incineration of wastes produces gaseous and particulate emissions which are significant in terms of quantities as well as potential importance in producing undesirable air pollution. The pollutants from waste burning include organics, aerosols, aldehydes, ammonia, acids, and

oxides of sulphur and of nitrogen. By combining known or estimated emission rates for municipal, commercial, back-yard and wood-waste incinerators and burning dumps with data furnished by local authorities on the relative quantities of wastes burned in the various types of incinerators, it is possible to estimate the total emission rates of the various pollutants.

Production of Solvent Vapors

Solvent vapors emitted from a large variety of domestic, commercial, and industrial operations represent a considerable source of significant air pollutants. Such operations as dry cleaning, painting and degreasing are typical of activities responsible for the evaporation of solvents. Emission rates may be estimated on the basis of quantities of solvents consumed or paint used in a given area. Such figures may be obtained from local distributors of these materials.

Miscellaneous Odor-Producing Activities

For the sake of completeness, an emission inventory should include a tabulation of sources giving rise to objectionable odors. Odors per se are not readily categorized according to their chemical composition, nevertheless information on the number and types of odor-producing activities is extremely useful in a community air pollution study. This list may include sewage and industrial waste treatment plants, stockyards, hog farms, as well as certain other industrial and agricultural activities producing malodors.

SPECIFIC SOURCE INVENTORY

Industrial plants comprise a category of air pollution sources presenting the widest range in quantities and types of air pollutants. Individually and collectively they represent a complex chemical system which, from an emission inventory standpoint, are most effectively treated directly on an individual basis. The Specific Source Inventory of a community has as its objective an evaluation of each major industrial source in that area. In the Special Air Pollution Study in Louisville, the procedures and techniques employed in each plant studied are as follows:

1. Initial Contact

An initial contact with industrial management, preferably a visit, allows an opportunity to explain the major purpose of the survey and specific objectives sought. It gives management an opportunity to become fully acquainted with activities to be scheduled in the plant. This procedure leads to a friendly basis of understanding and, in our own experience, to strong cooperation without which subsequent efforts would have been much more difficult, if not impossible in some instances. Where distrust or doubt can develop regarding motives and methods, confidence and good will may instead be established. This is particularly important later in the general acceptance of the findings which are made.

2. Preliminary Survey

The next important step in industrial source inventory methods is the preliminary survey. This is a brief but intent look at all of the factors which determine the type and extent of planning to be done prior to actual measurements or sample collection. While the procedures

involved in this step should be as simple as possible, the actual amount of effort required, naturally depends on the nature of the emissions and the complexity of operations or processes producing them. The activities included in the preliminary survey broadly include: (a) Briefing by management on processes and operations which contribute to emissions; (b) thorough physical inspection of these processes and operations and of the points of emission and (c) estimation by material balance or calculated values volunteered by management, on the types and quantities of effluents suspected of escaping into the atmosphere. These efforts may require anywhere from a day to a week, but are well worth the time.

Familiarity with processes and operations provides qualitative information on the nature of the effluents, such as their physical status, whether they are gases or particulates, hot or cool, wet or dry, released at atmospheric or at elevated pressures, etc. A simple flow diagram spotting the points of emission and indicating the details just referred to, serves as an excellent reference to be used in the guided physical inspection tour which follows.

A management representative conducts the tour and provides requested information. As each emission point is viewed, data regarding its physical location, accessibility, the availability of electrical power, the presence of safety hazards, the type and size of emission stacks or other venting equipment, the frequency and duration of venting and their relationships to operational cycles are all noted. Observing the effluents where possible, and even smelling or feeling them may provide useful information. Armed with the facts obtained from the process briefing and the inspection tour, significant points may be singled out to perform

some preliminary calculations on the expected amounts of certain pollutants and magnitude of stack velocities, etc. One may become good enough at this to reduce the number of samples required or measurements taken, but great care should be exercised in substituting such data for actual determinations.

3. Preparation

Proper regard for the preliminary survey will surely produce enough background information to allow adequate preparation for emission inventorying.

An obvious sequence in preparation is to decide on (a) what information needs to be ascertained, (b) what methodology is required, (c) how much and what type of equipment is needed, (d) the number and types of personnel required, and (e) a sampling and measurements schedule.

4. Sampling and Measurement-Particulate

Sampling and measurements are the next consideration. The number of methods is rapidly growing and adaptations become more numerous as new problems are encountered. Without attempting an exhaustive presentation of all published methods, some which have been successfully employed on the Louisville Study will be discussed.

The techniques used in determining particulate emissions can best be described by referring to the procedure actually employed at an industrial plant generating dust and fumes. This particular source study (Table I) was conducted in cooperation with technical personnel from the U. S. Bureau of Mines using equipment developed or modified by them.

Gas flow rates were determined for each stack source by the use of a type "S" Pitot tube, and the temperature was measured with an

integral thermocouple (Fig. 1). Gas flow rates from roof openings were determined by measurement with a Velometer. Temperature measurements were made with a mercury thermometer. Moisture content in stacks was determined by a hygrometer, and checked by measuring the amount of condensate collected during dust sampling. The integrated traverse method was used in all stack measurements (Figs. 2 and 3).

Dust loading samples were obtained from each stack on Whatman 43 x 123 mm double-thickness paper thimbles. The procedure employed is a modification of Western Precipitation Corporation procedure (Figs. 4 and 5). At roof openings, dust loading samples were taken with either a high volume sampler using type "G" filters, or an electrostatic precipitator.

Size frequency analyses of dust in the stacks were made on samples collected on Millipore filters, type AA, 47 mm diameter disks, held in a standard aerosol filter holder modified so that the entire unit could be inserted in the stack (Fig. 6). To accomplish this, the holder was fitted to various lengths of $\frac{1}{2}$ " I.P.S. stainless steel pipe and provided with a curved nose and a limiting orifice. Millipore samples were taken during time intervals varying from 1/5 sec. to 10 min. Deeply stained millipore disks may be used when sampling white dusts to make counting easier. Particles do not drop off the filters unless they are unusually large. The uniformity of particle concentration across the filter is good except when the stack contains water droplets. Very few agglomerates were observed. To count the finest particles, microscope immersion oil was used to make the filter invisible.

It is felt that this is an effective method for the determination of the types, quantities, and characteristics of emissions from this plant. This opinion is further supported by the fact that a comparison of results at this plant checked remarkably well with data collected by management by independent tests.

5. Sampling and Measurement - Gases

Gas sampling methods employed on the Louisville Study were developed to accommodate specific requirements encountered in industrial sources. One method which proved to be highly successful is the one developed by Brief and Drinker. This method (Fig. 7) is applicable to the collection of effluents produced by both cyclic and continuous operations where pollutants are discharged to the atmosphere through vents or stacks. The collection apparatus which comes in contact with the sample is constructed of glass throughout. It consists of an open-end mercury manometer, a two-liter grab flask surmounted by a manifold, a vacuum connector, a flushing piece, and a sampling probe. The manometer, the flask with manifold and the vacuum connector are assembled. The system is evacuated to below 1 mm Hg. The vacuum connector is replaced with a sampling probe with a flushing "T". The probe is first flushed with stack effluent. Purging is stopped and gases are let into the flask through valve "A" at a constant rate.

The amount of gas sampled is related to the rise in pressure in the flask as indicated by the manometer. The flow rate is controlled by the valve "A" which represents two orifices in series. If the gas sampled approximates air at one atmosphere pressure, constant flow is maintained across this stopcock until the flask pressure reaches 0.39 atmospheres.

This is the critical pressure ratio. Above this pressure in the flask, the flow rate must be maintained by adjustment of the stopcock. Advantages of this method are that the equipment is relatively inexpensive, light, and simple to use. Of great importance is the fact that the collected sample is easily transported to a distant point for analysis. This method lends itself equally well to short period or extended period sampling. The integrity of the sample is well maintained and transfer of the sample is uncomplicated.

A technique developed on the Louisville Study, especially for sampling gases exhausted through steam jets, employs the freeze-out principle. This method (Fig. 8), consists of bringing the sample through a condenser where all moisture is removed. The remaining gases pass into a liquid nitrogen-cooled freeze-out trap where they are condensed or frozen. Non-condensable gases, which should be of little interest from a pollution standpoint, are drawn through the system and exhausted through the vacuum pump. Pressure drop is regulated with the bleeder arrangement. This method offers the advantage of allowing the collection of gas from a stream of dry steam over any time period required, continuously or intermittently as desired.

Flow rate control is achieved by utilization of the pressure drop principle mentioned in the grab sampling technique above. The amount of moisture collected for a definite time period in the condenser is either measured or weighed. The rate of emission from the jet is then determined by calculation. The pounds of steam released through the jet is a constant depending on the steam quality, quantity, and pressure at the inlet of the jet. The rate of collection is compared to the total

emission rate. The quantity of pollutants collected bears the same relationship to the total quantity emitted (Fig. 9).

Samples collected by these two procedures may be subjected to any of the standard instrumental, physical, and chemical methods required. Most of the grab and freeze-out samples collected on the Louisville Study have been analyzed by Mass Spectrometry at the National Bureau of Standards.

Emission Estimates Based on Waste Liquor Losses

Another method of source sampling involves the determination of gaseous pollutants escaping in waste liquors either as volatiles present in the waste or those that result from chemical reactions in subsequent handling. As a case in point, consider the production of acetylene from crushed calcium carbide. Spent carbide leaving the generator may contain unreacted material which, upon subsequent handling and disposal, exposes fresh carbide to the waste liquors or to atmospheric moisture. Acetylene thus generated escapes and contributes to air pollution. Some acetylene gas is absorbed in the water as it leaves the generator. A sample of the liquor may be obtained in an evacuated flask and the dissolved gases determined. A sample of the solid material coming out of the generator on the other hand may be treated in the laboratory to complete the reaction of the carbide to determine how much additional acetylene may be generated under ideal conditions. Using a definite quantity of sample in such tests, permits calculation of potential acetylene losses based on total quantities of such wastes discharged.

Emission Estimates Based on Evaporation Losses

The next source sampling method of interest is that used in

determining losses of volatiles in an industrial operation treating wooden cross-ties for railroads. At this plant thousands of ties are creosoted and stored in the open, for a period of a year or more. The escape of volatiles to the atmosphere contributes to the air pollution.

In the approach used on the Louisville Study, borings are taken from ties which have been exposed to the atmosphere for varying lengths of time so that losses can be computed for different aging periods. Borings of a given aging period are steamed to remove the volatiles which may then be analyzed by mass spectrometry. Knowledge of the number of ties processed and the average time of exposure permits calculation of losses.

Conclusion

In summary, it is again emphasized that the approach employed in making an emission inventory is a function of the particular air pollution problem under investigation. A reasonably accurate estimate of emissions from multiple sources such as transportation, heat and power production and waste incineration can be made on the basis of such available figures as quantities of fuel and wastes burned in conjunction with knowledge of products of combustion. In the case of specific source studies, although standard procedures have been established for some types of sampling, modifications are often necessary. While the few examples mentioned here will by no means suffice for specific sampling problems which are bound to occur, they may serve as a guide in developing the appropriate approach.

LIST OF ILLUSTRATIONS

- Figure 1 Equipment for stack gas velocity and temperature measurements
- 2 Pitot tube traverse layout
 - 3 Pitot tube traverse layout
 - 4 Equipment for measuring dust concentration in stack gas
 - 5 Detail of dust-sampling probe
 - 6 Aerosol filter holder
 - 7 Apparatus for obtaining integrated gas samples
 - 8 Steam jet sampler assembly (Schematic)
 - 9 Steam jet sampler assembly (Photograph)

TABLE I - SOURCE SAMPLING SCHEDULE

SOURCE	MEASUREMENTS	DUST SAMPLING				GAS SAMPLING PERCENT			
		DUST LOADINGS		MILLIPORE SAMPLES		H ₂ O	CO ₂	SO ₂	SO ₃
		Gr/Ft ³	Lb/Hr	Particle Size Frequency Analysis	Spectro-Graphic & X-Ray Diffraction (% Comp.)				
Stack #1 - 60'	Gas Flow Rate (Ft ³ /Min)	X		X			X	X	X
Stack #1 - 160'	Temp. of.	X		X			X	X	X
Stacks #2 Lime Mill		X		X			X	X	X
Stacks #3 & #4 Coke Drier		X		X			X		
Stacks #5 through #10		X		X				X	
Roof Escape		X		X				X	

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